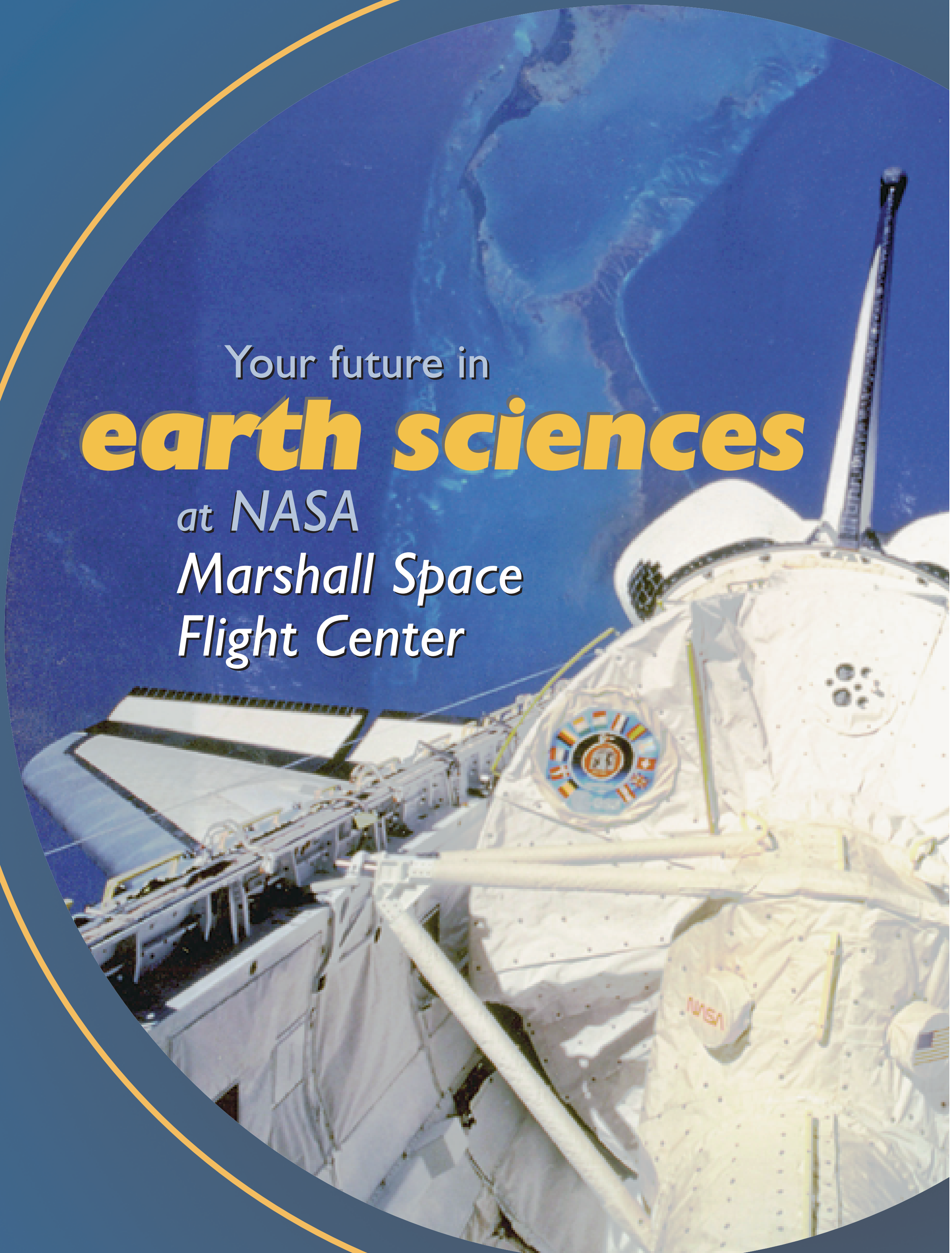
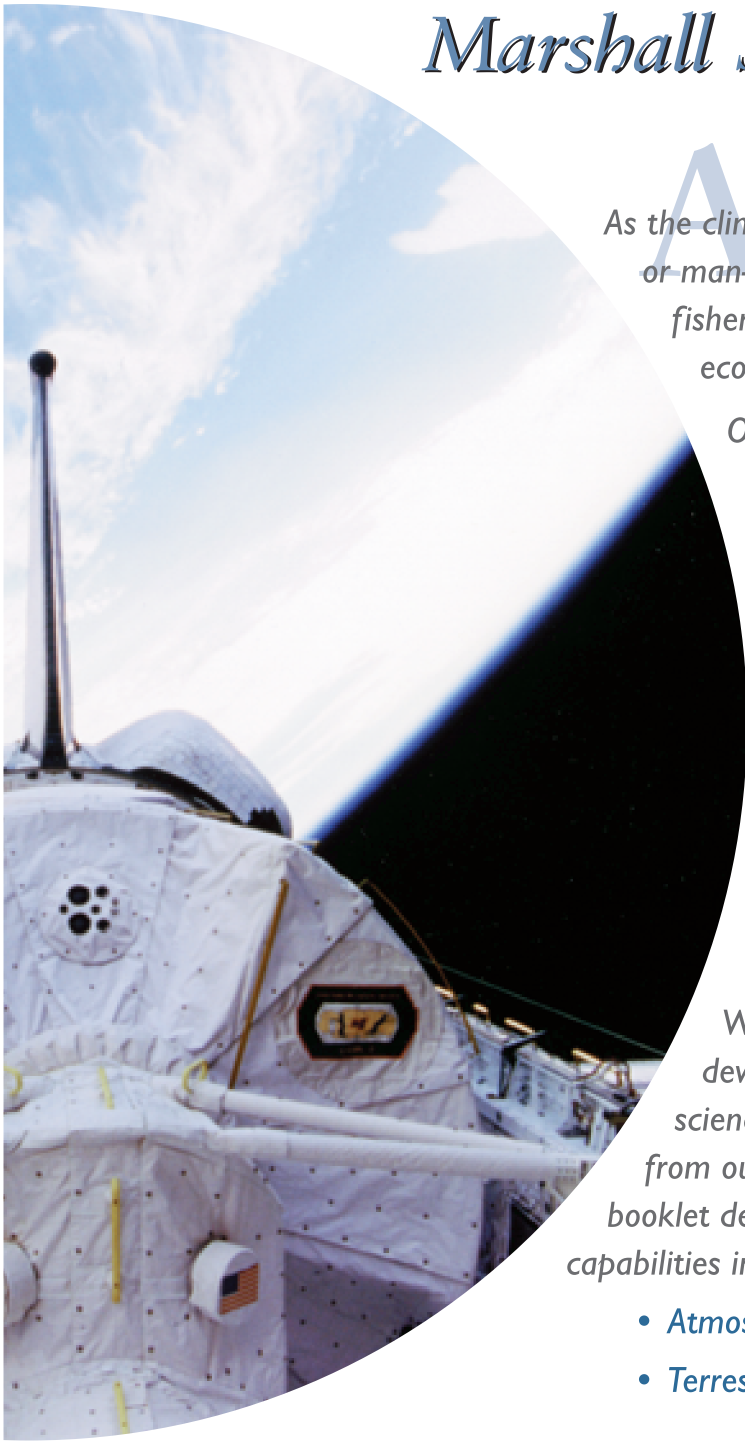
earth sciences

# Your future in earth sciences at NASA Marshall Space Flight Center



# Earth sciences at Marshall Space Flight Center



*As the climate on Earth changes—whether due to natural or man-made causes—it impacts crops, coastal lands, fisheries, human health, transportation, and the economy.*

*One of the many missions at NASA Marshall Space Flight Center is to work with our university and industry partners to study the state of Earth's atmosphere and land. These studies generate extensive data on the physical characteristics of our changing planet. By translating these data into useful information, Marshall and our partners can provide the tools needed to understand climate variations and improve U.S. economic competitiveness and the quality of life worldwide.*

*We invite you to partner with Marshall to develop new analytical techniques for earth sciences data, learn from our expertise, or benefit from our comprehensive facilities. This information booklet describes just a few of our research efforts and capabilities in the following areas:*

- *Atmospheric studies*
- *Terrestrial studies*

More information on Marshall's earth sciences activities is available via the Internet at http://www.ghcc.msfc.nasa.gov

## Marshall Partners with Atlanta to Improve Urban Air Quality

U.S. Environmental Protection Agency regulations are looming over the City of Atlanta. During decades of explosive population growth, the city converted vast acres of farmland and natural landscape into urban surfaces. This has led to an increase in the "urban heat island" effect and ozone buildup that dramatically degrade air quality. In response, EPA has required Atlanta to develop a plan for future air quality compliance or face a ban on new road construction. As a growing metropolis, Atlanta is badly in need of new roads.

Marshall Space Flight Center combined its research goals with Atlanta's needs to study how land use changes affect the region's meteorology and air quality. Using sensors aboard satellites and airplanes, Marshall acquired the data necessary to develop a better understanding of the urban heat island phenomenon, which led to the development and evaluation of solutions for Atlanta's air quality problems. Since then, nine more cities have joined the urgan heat island analysis program.

This booklet describes some of the capabilities available at Marshall that can help you achieve your earth sciences goals.

*Marshall's earth sciences capabilities can help industry and government understand the climate and improve U.S. economic competitiveness and the quality of life worldwide:*

### Natural Resources

- Agriculture
- Environmental industries
- Forest management
- Pollution abatement
- Water resources management

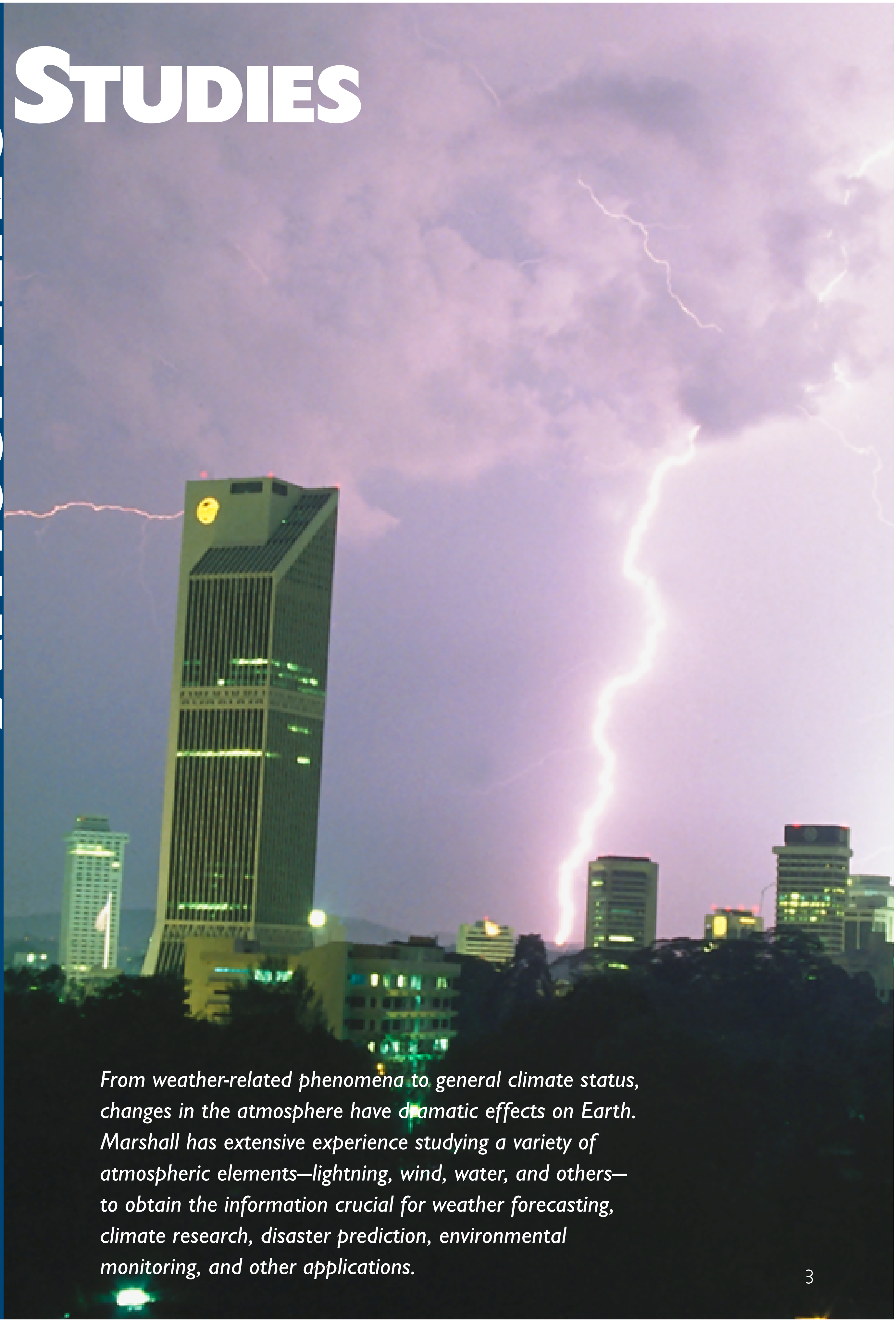
### Industry Advancement

- Aviation
- Civil engineering
- Construction
- Fisheries
- Maritime shipping

### Public Service

- Energy
- Meteorology
- Military
- Natural disaster preparedness
- Recreational safety
- Urban and regional planning

# Atmospheric Studies



*From weather-related phenomena to general climate status, changes in the atmosphere have dramatic effects on Earth. Marshall has extensive experience studying a variety of atmospheric elements—lightning, wind, water, and others—to obtain the information crucial for weather forecasting, climate research, disaster prediction, environmental monitoring, and other applications.*

## Lightning Detection

Each year in the U.S., lightning is responsible for the deaths of about 100 people, injuries to several hundred more, and millions of dollars in property damage and service interruptions. To detect severe storms faster and more accurately, Marshall uses several sensors to monitor lightning around the world.

### Lightning in the Tropics

Marshall uses space-based lightning imaging sensors to detect the distribution and variability of all lightning—in-cloud and cloud-to-ground—that occurs in the tropical regions of the world.

### Lightning around the Globe

Marshall's sensors can measure the occurrence of lightning virtually anywhere in the world. These space-based instruments consist of highly compact combinations of optical and electronic elements that can detect the momentary changes in a cloud scene. Marshall is also working to develop a space-based lightning mapper sensor to continuously map all forms of lightning and distribute this information in near–real time. Marshall is also pioneering electric field sensor design.

## *Applications for Marshall's Lightning Detection Capabilities*

*Researchers interested in using lightning data or furthering the science of lightning detection are encouraged to contact Marshall.*

### Meteorology
- Provide severe storm warnings

### Aviation
- Sense electric fields
- Ensure safe travel during electrical storms

### Utilities
- Design power distribution protection systems to withstand frequent lightning

### Forestry
- Detect forest and wildland fires

### Military
- Improve weather prediction for planning and logistics
- Optimize routes over ocean for safety and fuel efficiency

### Insurance
- Analyze data for damage and injury assessments

## The Future of Lightning Detection at Marshall

As our society becomes more dependent upon computers, information networks, and other electronic devices, protection from system disruptions becomes essential. One such protection comes from understanding thunderstorms and how and why they occur.

With further study, Marshall plans to improve estimates of convective rainfall rates using lightning flash rates and study developing weather systems by the evolution of lightning activity. Investigations will continue to focus on the relationship between global and regional lightning activity and rainfall. Field programs in the tropics will help develop and improve existing precipitation estimation algorithms while providing a better understanding of the coevolving electrical and dynamic structures of storms.

## Wind Studies

From breezes to gales to tornadoes and hurricanes, wind dramatically affects our lives. Marshall has advanced the science of wind studies with its expertise in coherent lidar—a key technique for monitoring wind. Coherent lidar determines the Doppler shift of backscattered radiation from a laser. The collected backscattered light is mixed with light from a local oscillator onto a light-sensitive detector.

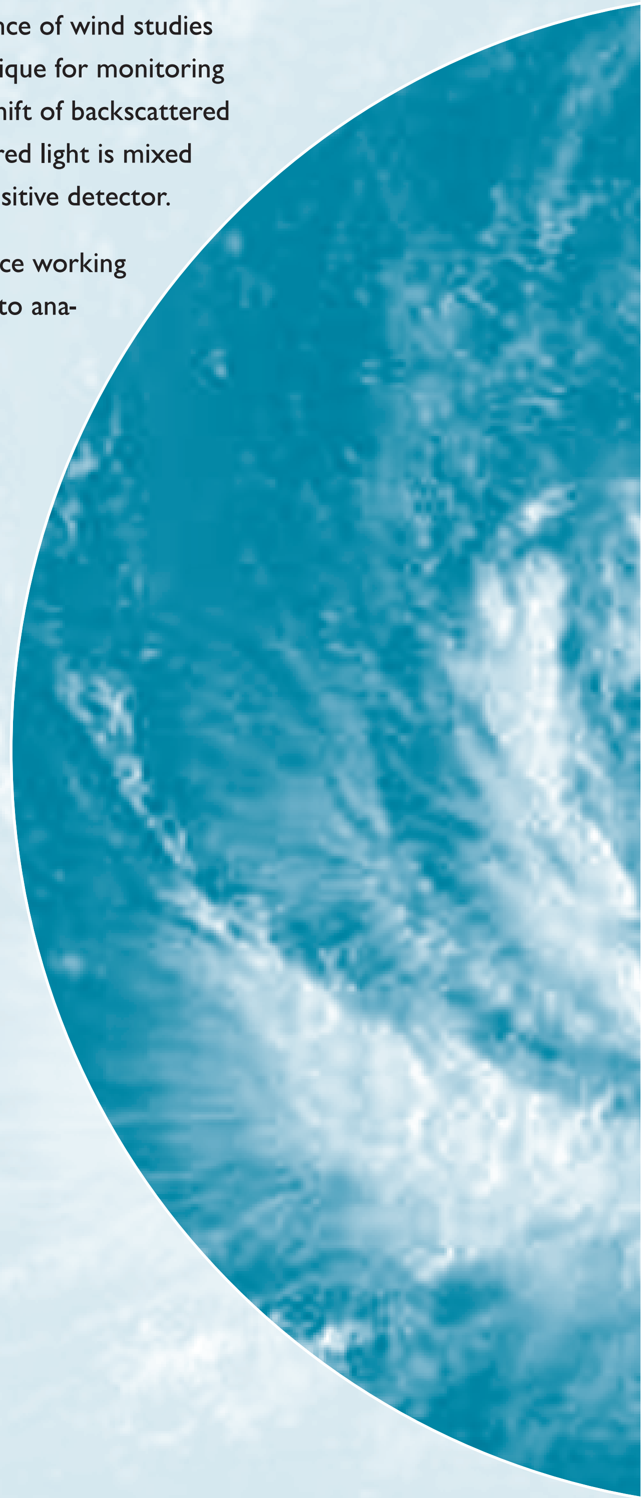
At Marshall, we not only have years of experience working with coherent lidar, we also have the expertise to analyze the data obtained.

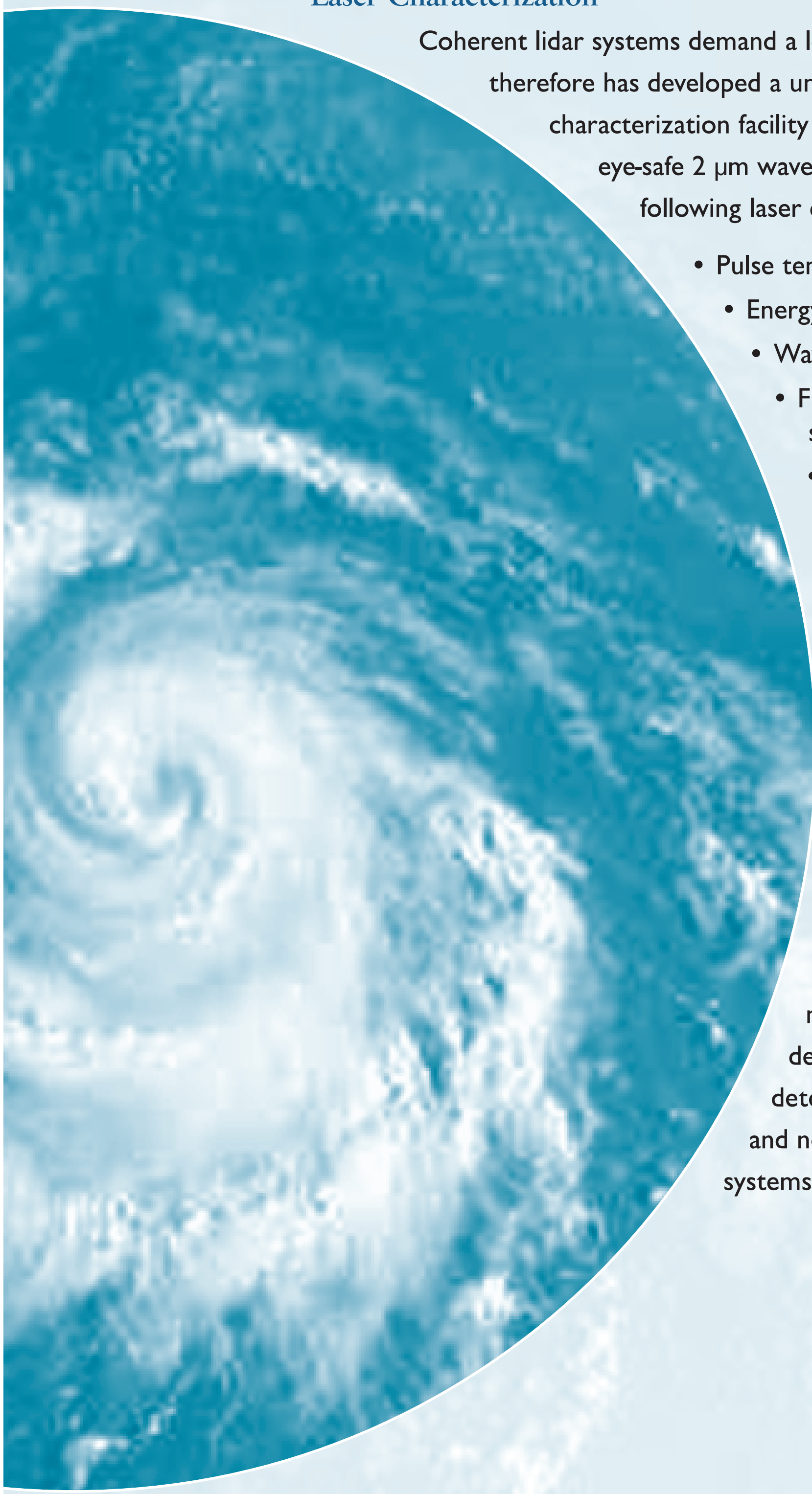
### Pulsed Coherent Lidar

Marshall uses an aircraft-based pulsed carbon dioxide laser that is coupled with an off-axis Mersenne telescope, a full hemispherical scanner, a complex receiver, and a Lassen "poly-pulse-pair" signal processor.

### Continuous-Wave Lidar

To support the coherent Doppler wind lidar studies, Marshall has developed continuous-wave lidars for accurate and sensitive measurements of atmospheric backscatter at two wavelengths. These instruments can be operated from an aircraft or from the ground.





## Laser Characterization

Coherent lidar systems demand a lot from their lasers. Marshall therefore has developed a unique, state-of-the-art laser characterization facility for testing lasers at the eye-safe 2 μm wavelength. We can examine the following laser qualities:

- Pulse temporal profile
- Energy
- Wavelength
- Frequency spectrum and stability
- Intrapulse frequency chirp
- Transverse pulse profile
- Polarization
- Beam divergence and quality

## Detector Characterization

Our detector characterization facility quantifies the performance of detection devices operating at 2 μm wavelength and provides all necessary data for the design, development, and calibration of detector subsystems for coherent and noncoherent solid-state lidar systems.

## *Applications for Marshall's Wind Study Data*

*Researchers seeking to benefit from our experience and expertise should contact Marshall to discuss possible partnership opportunities.*

### Weather Prediction

- Forecast weather conditions more accurately
- Prevent severe weather-related loss of life and property
- Increase evacuation warning time
- Decrease size of coastal evacuation areas

### Climate Analysis

- Study changing climate conditions (e.g., El Niño, global warming)
- Inform environmental policy decision makers

### Agriculture

- Plan crop layout
- Study pollination and seed dispersal
- Control agricultural pests

### Maritime

- Monitor winds for sailing conditions
- Optimize routes for fuel efficiency

### Energy

- Map wind fields for optimum siting of energy-producing windmills

### Environmental Industries

- Map wind fields for studying pollution transport
- Measure mass flow rate of high stack emissions

### Construction

- Design buildings to withstand severe weather

### Military

- Improve targeting for military ordnance and for parachute-dropped personnel and supplies
- Control weapon fire
- Monitor wind during rocket launch

### Aviation

- Monitor wind turbulence, wind shear, and wake vortices for safer take-off and landing at airports
- Optimize routes for fuel efficiency

### Urban Planning and Civil Engineering

- Map wind fields to study their effects on planned or existing structures

## The Future of Wind Studies: SPARCLE

SPARCLE, which stands for SPAce Readiness Coherent Lidar Experiment, is being developed at Marshall Space Flight Center to close the biggest gap in global measurements—three-dimensional wind data. By obtaining direct tropospheric wind measurements using lidar from the Space Shuttle, the experiment is expected to lead to dramatic advances in the understanding of atmospheric processes and in weather prediction.

The experiment consists of a test version of a large-scale laser that could someday measure winds across the planet from satellites. Using a compact optical system, SPARCLE will aim pulses of eye-safe laser light into Earth's atmosphere and measure the light reflected back by atmospheric dust and aerosols. By analyzing a series of pulse echoes, scientists will be able to measure the movement of clear air.

### *Applications for Marshall's SPARCLE Data*

*Researchers and the academic community worldwide will need to process SPARCLE's massive data sets.*

Some of these efforts will include:

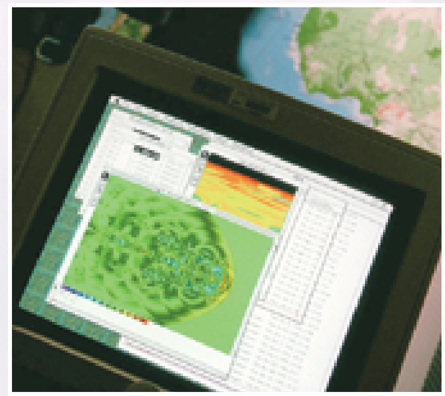
- Velocity estimation
- Numerical weather model improvement
- Line-of-sight wind data validation
- Doppler wind lidar simulation model validation
- Phenomenological research (e.g., hurricanes, El Niño)
- Data assimilation algorithm testing
- Atmospheric process studies

## Studying the Water Cycle

Understanding the hydrologic cycle is essential for monitoring Earth's atmosphere and climate. Marshall uses aircraft- and satellite-based instrumentation to obtain the data needed to advance this understanding. We also have extensive experience using various atmospheric modeling tools to understand the water cycle. This expertise can benefit researchers and global data analysts throughout the nation and abroad.

### Data Gathering

Marshall gathers information on a variety of water cycle parameters.



#### *Precipitation*

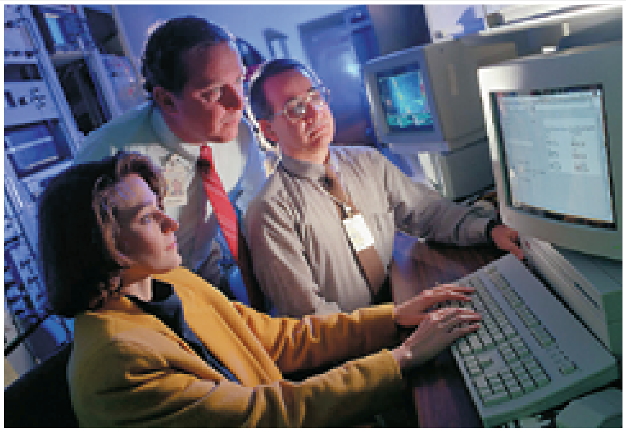
Precipitation provides water to the biosphere, making our planet habitable. Precipitation can also have devastating effects, causing flash floods, soil erosion, and runoff of livestock waste and agricultural chemicals into watersheds used for drinking water. Marshall estimates rain rates over both land and ocean.

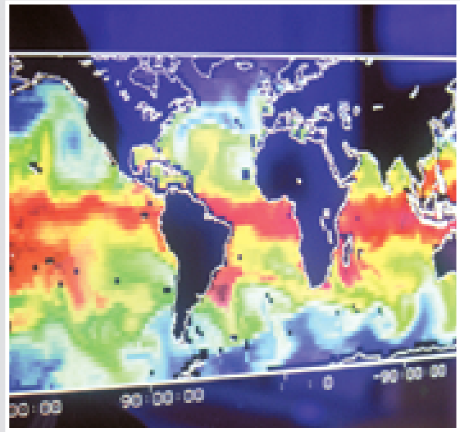
#### *Cloud Water Content*

Marshall estimates the water levels of clouds over the ocean to determine whether clouds increase or decrease under various conditions. Since clouds reflect sunlight, their prevalence may affect global warming.

#### *Water Vapor*

Measuring the total integrated water vapor of the atmosphere is important for understanding how water is cycled through the atmosphere and how global warming may affect this process. Since water vapor absorbs heat energy, it plays a major role in climate change.





## Atmospheric Modeling

Accurately representing the water cycle in climate models makes them useful diagnostic tools in predicting climate trends. Marshall uses a variety of atmospheric modeling tools to study global water cycle parameters.

### *Regional*

Marshall produces real-time weather models for the Southeast and the continental U.S. Available via the Internet, these models provide two-day forecasts for a variety of atmospheric parameters:

- Surface temperature
- Surface wind
- Dew point
- Pressure
- Relative humidity
- Precipitation and accumulation

### *Land Surface*

Marshall's land surface energy flux model is used to describe the entire physical state of the surface, planetary boundary layer, and subsurface. The system is driven by eight atmospheric forcing variables, which are supplied by field measurements or other models. Separate visible and near-infrared surface radiation reflections are determined based on vegetation type and solar zenith angle.

### *Diagnostic*

Scientists at Marshall are developing a "water budget" diagnostic model designed to estimate the three-dimensional fields of vapor, cloud condensate, and precipitation around the globe as a function of time. The analysis is designed to output more than 70 global horizontal fields every 12 hours, along with vertical profiles and zonal mean cross-sections of numerous parameters.

### *General Circulation*

Marshall uses the atmospheric general circulation model to predict long-term atmospheric dynamics. This model can be used to study how a specific environmental variable (e.g., sea surface temperature) affects the atmosphere.

### *Mesoscale*

Our recent mesoscale modeling research has focused on numerical experiments using a nonhydrostatic cloud model. The objective has been to examine the relationship between vertical mass flux in deep convection and microphysical processes in a variety of convectively active environments.

## Other Atmospheric Measurements

A healthy atmosphere is essential for a healthy planet. Marshall therefore undertakes a variety of studies to monitor the state of the atmosphere. This research has wide-reaching benefits.

### Atmospheric Aerosols

Atmospheric aerosols—whether released through natural events or through biomass burning for construction and agriculture—affect the regional and global radiative balance. Satellite observations of aerosols can be used to determine the effect on Earth's climate.

### Multispectral Atmospheric Mapping Sensor

This aircraft-based sensor measures reflected radiation and thermal emission from Earth's surface, clouds, and atmospheric constituents.

### Globally Averaged Atmospheric Temperatures

Surface temperature measurements indicate that Earth's temperature is rising, while satellite measurements of temperatures in the lower atmosphere show no significant trend. These differences are the basis for discussions over the existence and magnitude of any possible global warming

## Benefiting the Research and Industrial Communities

Marshall offers a variety of programs and products to facilitate the practical uses of the data obtained in our atmospheric studies.

### Data Archiving and Distribution

Marshall and its partners have established the Global Hydrology Resource Center to store and make available the lightning, water vapor, temperature, and microwave data discussed in this booklet. Researchers, educators, and others can request these data through the center's Internet site (http://wwwghrc.msfc.nasa.gov).

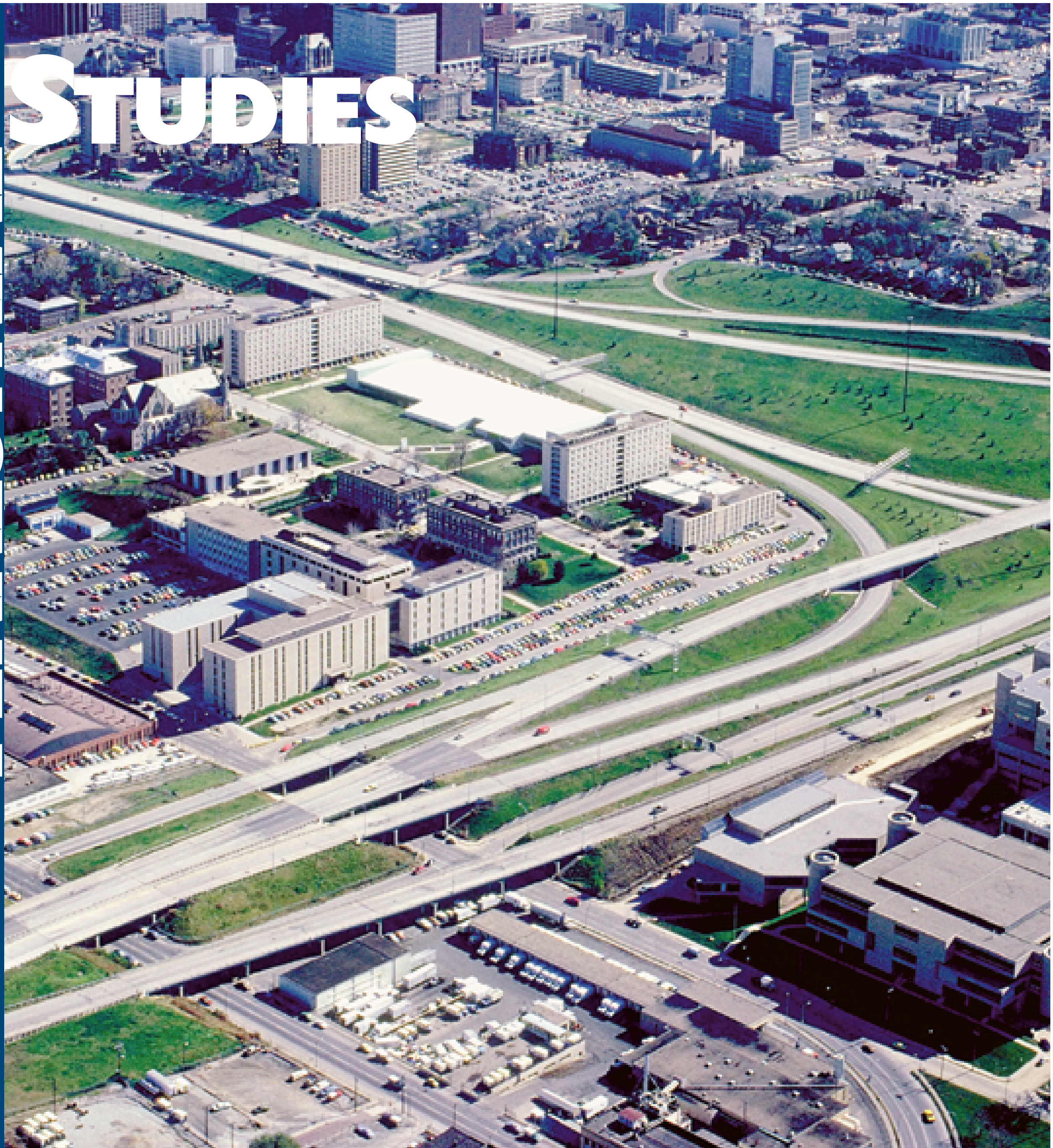
### Satellite Images and Data

Marshall receives global geostationary satellite data through local antennas and from receiving stations around the world. These data represent clouds and atmospheric features as observed with visible and infrared sensors. Geophysical parameters can be produced with these data for a variety of investigations. Data can be viewed, with zooming and animation capabilities, or downloaded via the Internet (http://www.ghcc.msfc.nasa.gov/GOES).

### Regional Impact Assessments

As part of a presidential initiative to study the nationwide consequences of global climate change, Marshall and its partners are leading the regional assessment activity in the Southeast. We facilitate communication between researchers and stakeholders, coordinate periodic regional assessments of climate variability and change, and increase public understanding of climate change and its potential effects on their lives.

# Terrestrial Studies



*At Marshall, we seek to understand the interaction between human activity on land and Earth's natural processes. Terrestrial phenomena, such as urban heat islands, play a key role in the health of our cities. Surface winds and surface wetness affect pollination and crop production. And information from archeological studies examining how ancient people interacted with their environment can be applied to modern day societies.*

## Urban Heat Island Detection System

Urban surfaces such as rooftops and pavement absorb sunlight and build up heat. When the heat is released after sunset, a dome of higher temperatures is formed over the city. This is known as the urban heat island phenomenon. Marshall has extensive experience studying urban heat islands using satellite data, thermal sensors, computer models, and geographic information systems.

### Satellite Data

Several satellites and space-based instruments provide data on land cover and land surface thermal characteristics.

### Sensor Data

An airborne multispectral thermal sensor obtains data on thermal energy fluxes on specific surfaces (e.g., pavement, buildings) and the changes in thermal energy response for these surfaces between day and night.

### Computer Models

Satellite and sensor data are incorporated into computer modeling systems that calculate atmospheric parameters for studying interactions between land use and regional meteorology.

### Geographic Information Systems

Marshall has the GIS capabilities to support mapping, remote sensing image processing, and associated data assimilation. Our equipment includes numerous computer systems, a video lab, scanners, and high-quality printers.

## *Applications for Marshall's Thermal Sensing Capabilities*

*Cities, regions, and states interested in participating in the land use analysis program are encouraged to contact Marshall, as are others interested in pursuing thermal sensing research.*

### Urban Planning and Civil Engineering

- Lower urban summer temperatures by changing the color of urban surfaces and by planting more "urban forests"
- Study how people and infrastructure are vulnerable to climate variability
- Improve urban quality of life

### Energy

- Study climate's effect on activities that use energy (e.g., air conditioning, transportation services)
- Promote use of sustainable energy sources
- Reduce greenhouse gas emissions

### Medicine and Human Health

- Study the health effects of air pollution coupled with heat stress
- Study the health effects of changes in weather extremes

### Ecology

- Preserve resources in national parks, monuments, and wilderness areas
- Protect endangered species
- Maintain biological diversity to preserve genetic resources and protect ecosystem viability

## Other Surface Studies

Marshall uses an advanced microwave scanning radiometer (shown above mounted on a crane) to study various surface parameters. The twelve-channel, six-frequency total power passive microwave radiometer system consists of an offset parabolic reflector 1.6 meters in diameter, fed by an array of six feed-horns. The reflector and feedhorn arrays are mounted on a drum that contains the radiometers as well as the subsystems for digital data, mechanical scanning, and power.

### Surface Wetness

An adequate understanding of the links between soil moisture and evaporation is essential to predict how land surface processes affect weather and climate.

### Surface Wind Speed

Data obtained from measuring ocean surface roughness can be converted into a near-surface wind speed.

### *Applications for Marshall's Surface Studies Data*

*Researchers interested in using the data obtained in our surface studies are encouraged to contact Marshall.*

- Maintain crop and vegetation health
- Monitor for drought
- Make informed planting, irrigation, and other agricultural decisions
- Optimize ship routing for fuel efficiency
- Monitor winds for sailing conditions

## Archeology

One of the goals of archeology is to determine what factors may have led to the collapse or disappearance of ancient civilizations. Modern day societies can benefit from studying the successes and mistakes of the past.

Marshall's use of remote sensing technology enables archeologists to detect the impacts of human actions upon the environment. Remote sensing rapidly and accurately images the surface and shallow-depth archeological information often invisible to the naked eye.

Marshall has experience with a variety of remote sensing instruments. Archeologists and other researchers are encouraged to contact Marshall to find new uses for remote sensing data.

### Color Infrared Film

Marshall uses CIR film to detect wavelengths slightly beyond the red end of the light spectrum. CIR photography is sensitive to very slight differences in vegetation, making visible the archeological features that affect how the plants above them grow.

### Thermal Infrared Multispectral Scanner

The TIMS six-channel scanner measures the ground's thermal radiation with accuracy to 0.1 °C. The scanner's resolution capabilities make it ideal for archeological research. Marshall has used TIMS data to detect ancient Anasazi roads in Chaco Canyon, New Mexico and prehistoric footpaths in Costa Rica.

### Microwave Radar

As it beams radar pulses into the ground and measures the echo, microwave radar can find buried features in arid regions. Man-made objects tend to reflect the microwaves, giving a picture of what is underground without disturbing the site.

### Synthetic Aperture Radar

Whether used in space-based or aircraft-based experiments, SAR beams energy waves to the ground and records reflected energy, identifying linear and geometric features. The technology has revealed ancient watercourses in the Sudanese desert and prehistoric footpaths in Costa Rica.

## Technology Transfer at NASA Marshall Space Flight Center

*This information package has been assembled as part of NASA Marshall Space Flight Center's technology transfer program. The primary goal of the technology transfer process at Marshall is to encourage broader utilization of Marshall's technologies, unique combination of facilities, and data-analysis capabilities in the U.S. academic, governmental, and industrial communities.*

*We invite you to contact Marshall to discuss possible partnership opportunities and availability of facilities.*

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